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54 **OPTICAL COUPLING DEVICE.**

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Description

The present invention relates to optical coupling devices. It finds particular application in maintenance, or fault finding, in optical communications systems.

It is sometimes advantageous to couple optical radiation into or out of a waveguide at a point other than at an end. For instance, when jointing optical fibres it is known to align the fibre ends to be jointed by feeding light from one fibre end into the other and manoeuvring them relative to one another to maximise coupling between the fibre ends. To do so, a bend is produced in the fibres to each side of the jointing region and the light is injected at the bend in one fibre and monitored by picking it off at the bend in the other fibre.

Although this technique for injecting and picking off light has the advantage that little preparation of the fibre has to be done, that is, it can be carried out for instance through a protective polymer coating carried by a fibre, there are circumstances in which it is unsuitable. The technique injects a relatively high power level of light and picks off as high a proportion of the light injected as possible. There are applications in which it is still advantageous to pick off radiation at a point along a fibre other than at an end, but in which it is preferable that only low power levels are picked off. For instance, in an optical fibre communications system, one may wish to detect a malfunctioning fibre amongst working fibres. If one were to test for the malfunctioning fibre by picking off high power levels from random fibres, the transmission of one or more working fibres is likely to be interfered with.

Optical couplers are known which can be used to couple an adjustable power level of light into, or from, an optical fibre, but they rely on careful preparation of the fibre. For instance, in one type, the core glass of the fibre has to be brought close to the fibre surface by mounting the fibre in a curved position and polishing away the cladding glass on the outside of the curve until fibre core glass is almost exposed. Light is then coupled into, and out of, the exposed core of the fibre by controlling the relative position of a second fibre which has been polished in the same manner.

Optical couplers of this type suffer from the disadvantages that they are time-consuming and expensive to produce. A monomode fibre typically has an outer diameter of 125 μ m and a core diameter of only 9 μ m. Hence, it is difficult to control the polishing steps with sufficient accuracy. The couplers are also limited in that they can only be used at predetermined fixed positions along a prepared fibre. Furthermore, the arrangement tends to be vulnerable and unsuitable for use in the field.

Another known type of optical coupler is described in GB-A-2 126 749. In this coupler, light guided by an optical fibre is tapped to a detector by substantially surrounding a portion of the fibre with a tube and by bending the fibre and the tube. The tube couples a portion of the optical energy carried by the fibre to the detector.

The aim of the invention is to provide an optical coupling device which can conveniently be used to test optical fibres in use in an optical communications system.

The present invention provides an optical coupling device for coupling low power levels of optical radiation out of an optical fibre having a primary coating of plastics material and a refractive index of n_1 at or near its surface, the coupling device comprising a pick-up element having a refractive index n_3 and providing a curved optical waveguiding path therein, and retaining means for retaining the optical fibre in a curved position which at least substantially conforms to the inner surface of the curved path, the refractive indices of the pick-up element and the surface of the optical fibre, n_3 and n_1 , and the radius of curvature, R , in mm of the inner surface of the curved path portion of the pick-up element being chosen such that $n_3 > n_1 (1 - 0.125/R)$, R being greater than or equal to 3, characterised in that the retaining means is constituted by a clamping means comprising a block of material having a convex surface, a groove being provided in the convex surface to locate the optical waveguide over the convex surface, and means for holding the block and the pick-up element together so as to grip the optical fibre positioned in the groove, and the clamping means is such as to grip the optical fibre sufficiently tightly to distort its primary coating so that, in use, optical radiation is leaked from the optical fibre, and coupled into the curved path.

Preferably the clamping means is movable relative to the pick-up element.

It has been found that a relatively simple coupling device can be designed according to embodiments of the present invention which will pick up sufficient radiation from the optical fibre to check whether the fibre is functioning, without significantly disturbing a communications system dependent on the functioning of the fibre.

A waveguiding path in this context is intended to mean a path along which optical radiation will be guided by means of the distribution of refractive index in the materials of the waveguiding path. In general, a waveguiding path will comprise, in cross-section, a core region of one refractive index, surrounded by a cladding region of a lower refractive index or range of refractive index.

In order that optical radiation coupled into the curved path does not return to the optical fibre, the

refractive index of the material of the path should preferably be greater than that of the optical fibre.

Conveniently, the pick-up element comprises a solid curved rod of a dielectric material such as silica.

The radiation from a curved optical fibre does not leak away uniformly with distance along the fibre, but in a series of discrete, well-defined, tangential beams. These beams form a divergent pattern, angular separation of the beams being a function of bend radius of the fibre. Both the bend radius and the length of the curved optical fibre which is curved are factors which affect the power level of optical radiation coupled out of the optical fibre. For optical communications systems, using 1300nm radiation transmitted by monomode fibres, a suitable radius of curvature of a fibre to couple out sufficient power for testing purposes without significantly degrading transmission has been found to be of the order of 15mm, the total length of curved fibre subtending an angle of about 120°. Using such an arrangement, the loss introduced to the system may be of the order of only 3dB.

We have also found that efficient coupling is facilitated by extending the pick-up element so that it and the optical fibre are aligned not just over the aforesaid curved portion, but also over a straight path thereafter. Although the length of the straight portion is not finely critical, we have found that optimum performance is obtained when it is about twice the diameter of the bend. Shorter lengths can be used of course but satisfactory coupling out of the cladding modes is increasingly difficult to achieve as this length is reduced. Greater lengths can be used where they are not inconvenient and where attenuation in the pick-up element is not a problem, but in general little useful power remains in the cladding much beyond the double diameter point.

It has been found that devices according to embodiments of the present invention can couple power levels of optical radiation out of an optical fibre which has a primary protective plastic coating intact as low as about 1nW. To avoid significant interference with a monomode fibre communications system, typically the power level of the optical radiation coupled out of a fibre should be less than or equal to 50% of the average power level of optical radiation being transmitted by the fibre.

A coupling device may conveniently be applied to an optical fibre at a point in a communications system where the primary coating of the fibre is exposed for routing purposes. For instance, this is generally the case in joint housings, and at distribution points.

An optical coupling device according to an embodiment of the present invention will now be described, by way of example only, with reference

to the accompanying figures in which:

Figure 1 shows a side elevation of the optical coupling device in use;

Figure 2 shows an exploded, three-quarter view of the optical coupling device of Figure 1; and

Figure 3 shows a side elevation of a component of the device of Figure 1.

The figures are not drawn to scale.

Referring to Figure 1, the optical coupling device comprises a silica rod 1 having a curved and a straight portion, and a block 2, which co-operate to clamp an optical fibre 3 against the inner surface 4 of the curved portion of rod 1. Optical radiation which leaks out of the clamped optical fibre 3 in use is then picked up by the curved portion of rod 1 and guided to a photodetector 6 to be converted to an output signal.

Preferably, as indicated above, the curved portion of the rod is followed by an extended straight portion against which the fibre is also clamped. Such an arrangement is shown in Figure 1a. In this example the angle θ° is 30°, the lengths L and M are each 20mm, and the radius R is between 3 and 11mm.

Referring to Figure 2, the rod 1 has a square cross section with sides of 2mm. The curved portion has a substantially constant radius of curvature R (to the inner surface 4) of 8mm, and subtends an angle of 160° at its centre of curvature. The end of the rod 1 adjacent the curved portion is polished to give a smooth finish.

A convenient method of making the rod 1 is to cut a 2mm annular length from the end of a silica tube, the tube having a 16mm internal diameter, and 2mm wall thickness. Each flat end face of the annular length is polished and a segment then removed, to leave a C-shaped portion. One end of the C-shaped portion is then straightened outwards to form the straight portion of the rod 1.

Mounted on the end of the rod 1 adjacent the straight portion is the photodetector 6. Devices suitable for use in detecting light in these circumstances are known and further details are not therefore given. Clearly it will be necessary, however, that whatever is used to detect the light must be capable of responding to optical power levels as low as those which will be encountered in use of the coupling device.

The block 2 comprises an optically opaque plastics material and has a side elevation which is substantially D-shaped. It is flat-sided and has a thickness of about 20mm. The major part of the curved surface 7 is curved to match the shape of the inner surface 4 of the curved portion of the rod 1. The length of the curved surface 7 is greater than that of the rod's inner surface 4, however, so that when the coupling device is assembled, as shown in Figure 1, the block 2 protrudes from the

curved portion of the rod 1.

The curved surface 7 of the block 2 is provided with a central, V-profile groove 8. The groove 8 is 0.1mm deep and its sides meet at 60°. This allows it to locate a monomode optical fibre 3 which has its primary protective plastics material coating in place, the fibre 3 projecting slightly from the groove 8. Typically such a fibre, for use in an optical communications system, will have an outer diameter of about 250µm.

Means are provided (not shown) for holding the block 2 and rod 1 together so that a fibre 3 located in the groove 8 is brought into contact with the inner surface 4 of the curved portion of rod 1. A simple, spring clip device or the like is suitable for holding the block 2 and rod 1 together, the force exerted by the device being sufficient to retain the coupling device in an assembled position without causing damage to the protective plastics material coating of the fibre 3. Alternatively, the block 2 and rod 1 may be pivotally coupled together so that an optical fibre 3 may be gripped between them as in a pair of pliers.

The output 9 from the photodetector 6 may be coupled to any equipment which it is intended should respond to it. For instance this may be a simple indicator, such as a light emitting diode, to show whether or not optical data is being transmitted by the fibre 3 under test.

In use, a fibre 3 to be tested is placed between the block 2 and the curved rod 1, lying in the groove 8 of the block 2. The fibre 3 is gripped sufficiently tightly to distort the primary coating slightly, into the groove 8 and against the rod 1. Because the fibre protrudes from the groove 8, the curved rod 1 is held away from the block 2 by the fibre 3. This means that the silica walls of the rod 1 are surrounded by air, except where the protective coating of the fibre 3 contacts the rod 1. The refractive index of the material of the rod is 1.49. Hence, except where radiation is to be coupled into the rod 1, the walls of the rod 1 in combination with the air fulfil the criterion of a waveguiding path. That is, together they constitute a core region of one refractive index (the silica rod 1) surrounded by cladding regions of a lower refractive index (the air). Because the difference in refractive indexes of the two regions is relatively high, 0.49, the rod 1 is strongly waveguiding and acts to "capture" a significant proportion of the optical radiation which might be leaked from the fibre 3.

It may be found advantageous to use an index matching material, such as a fluid or gel, to couple the optical radiation out of the fibre 3 into the rod 1.

By using a block 2 of optically opaque material, the block 2 acts as an optical seal. It acts to reduce the amount of extraneous radiation, not carried by the fibre 3, which might enter the rod 1

and affect the response of the photodetector 6.

It is important that optical radiation leaked from the optical fibre 3 in use of the coupling device is not only picked up by the rod 1 but also guided to the photodetector 6. In view of the fact that the rod 1 is curved in the same manner as the optical fibre 3, there is a possibility that the radiation leaked from the fibre 3 will equally leak from the rod 1. If the rod 1 designed to be too strongly guiding, then there can be a difficulty in getting radiation out of the rod 1 to the detector 6.

Referring to Figure 3, in order to design a useful coupling device according to an embodiment of the present invention, the following relationships should be applied:

$$i) \quad n_3^2 < (n_1^2 (1-0.25/R) + (0.125/R)^2 + 1)$$

$$ii) \quad n_3 > (n_1 (1-0.125/R))$$

$$iii) \quad t < 0.44R-0.18$$

where

n_3 is the refractive index of the rod material;
 n_1 is the refractive index of the optical fibre cladding material (ie the material at the fibre surface);

t is the thickness in mm of the rod 1 in the plane normal to the interface between the rod 1 and the fibre 3 (not shown); and

R is the radius of curvature in mm of the inner surface 4 of the curved portion of the rod 1.

The upper limit given for n_3 by relationship i) is designed to allow the radiation picked up by the rod 1 to exit to the photodetector 6 rather than be reflected at the end of the rod 1. Use of an index matching material between the rod end and the detector or whatever is at the end of the rod may enable this limit to be exceeded. The lower limit given by relationship ii), in combination with the t, R relationship iii), is designed to cause internal reflection of radiation picked up by the rod 1 at the outer side of the curved portion of rod 1, thus preventing too significant losses from the rod 1.

Each of the relationships i) to iii) is given for a rod 1 surrounded by air. If the optical fibre 3 is a monomode fibre of the type commonly in use today in optical communications, then the refractive index n_1 will have the value 1.456.

The second two relationships in particular, designed to reduce losses at the outer side of the curved portion of rod 1, are calculated with regard to radiation leaving the optical fibre 3 tangentially and are not intended as strict mathematical treatments of the design limits of a design coupler as described.

Where the radius of curvature and/or the thickness of the rod are not constant, satisfactory results should still be obtained if the relationships are each satisfied for every part of the rod that contributes to the coupling.

Using optical radiation of wavelength $1.3\mu\text{m}$ in the fibre 3, it has been found that an optical coupling device as described above, having the relevant associated values $R = 8\text{mm}$, $t = 2\text{mm}$, $n_1 = 1.456$, and $n_3 = 1.49$, produced 3dB loss in the signal carried by the fibre 3 and had 20% efficiency. That is, of the radiation leaked from the fibre 3, about 20% was collected and guided to the photodetector 6. If the optical radiation is of wavelength $1.5\mu\text{m}$, then the loss from the fibre 3 is increased. If the radiation is left at $1.3\mu\text{m}$ but the radius of curvature R referred to above is decreased to 6 mm or 5mm, then the loss from the fibre 3 is increased to about 6dB and 10dB respectively.

To reduce losses at the interfaces produced by the primary coating of the fibre 3 with the cladding of the fibre 3, and with the rod 1, preferably the refractive index of the primary coating should lie between that of the fibre cladding, n_1 , and that of the rod 1, n_3 .

Variations may be made from the above described embodiment of the present invention. For instance the rod 1 may have a circular, or other rounded, cross section. Instead of having just rod-like member to pick up radiation leaking from the fibre 3, it may be found convenient to use some larger structure which has a curved waveguiding path embedded therein. For instance, this might have the advantage that it would then be possible to mount the block 2 directly into a structure by means of, for instance, a snap fitting. In this way, the need for independent means to hold the rod 1 and block 2 together would be avoided. Further, the structure used could enable the fibre in an assembled coupling device to be protected from damage.

In another alternative arrangement, two photodetectors may be used, for instance one being mounted at each end of the rod 1. This introduces directivity, useful if the fibre 3 concerned is carrying duplex transmissions, or could be used to improve sensitivity by cancelling background effects.

Although in the device described above, the curved portion of the rod 1 subtends an angle of 160° at the centre of curvature, this angle can be varied. For instance it might be reduced to 60° or increased to 180° . However, if it is reduced too much, the device tends to become insensitive in that either sufficient light can not be leaked from the fibre 3 for the photodetector 6 to distinguish or the amount leaked has to be leaked over such a

short distance that the losses from the fibre 3 are difficult to predict. If the angle were to be increased beyond 180° , the device becomes physically more difficult to apply to a fibre.

It is not of course necessary that the curved portion of rod 1, or other curved, optical waveguiding path, should conform to part of a circle. That is, the associated radius of curvature does not have to be constant. If it is not, then the angle between the normals to the curved path, at each end of that path, should preferably meet at an angle which lies in the range from 60° to 180° inclusive, more preferably from 90° to 180° inclusive.

Although described above for use with a primary-coated optical fibre, a coupling device according to an embodiment of the present invention may alternatively be used with a fibre having a further secondary coating in place, for instance of nylon or other material, as used in optical fibre cable technology for additional protection.

Claims

1. An optical coupling device for coupling low power levels of optical radiation out of an optical fibre (3) having a refractive index of n_1 at or near its surface and having a primary coating of plastics material, the coupling device comprising a pick-up element (1) having a refractive index n_3 , the pick-up element (1) comprising a waveguiding path at least part of which is curved to form a curved optical waveguiding path, the coupling device also comprising retaining means for retaining the optical fibre retaining means for retaining the optical fibre in a curved position which at least substantially conforms to the inner surface (4) of the curved path, the refractive indices of the pick-up element and the surface of the optical fibre, n_3 and n_1 , and the radius of curvature, R , in mm of the inner surface of the curved path portion of the pick-up element being chosen such that $n_3 > n_1(1 - 0.125/R)$, R being greater than or equal to 3, characterised in that the retaining means is constituted by a clamping means comprising a block (2) of material having a convex surface, a groove (8) being provided in the convex surface to locate the optical waveguide (3) over the convex surface, and means for holding the block and the pick-up element together so as to grip the optical fibre positioned in the groove, and the clamping means is such as to grip the optical fibre sufficiently tightly to distort its primary coating so that, in use, optical radiation is leaked from the optical fibre, and coupled into the curved path.

2. A device as claimed in claim 1, wherein the clamping means is movable relative to the pick-up element.
3. A device according to claim 1 or claim 2, wherein
- $$n_3^2 < (n_1^2 (1 - 0.25/R + (0.125/R)^2 + 1)).$$
4. A device according to any one of claims 1 to 3, wherein the thickness of the pick-up element (1) in mm in the plane normal to the interface between the pick-up element and the optical fibre (3) is less than $0.44R - 0.18$.
5. A device according to any one of claims 1 to 4, wherein the pick-up element (1) is rigid and self-supporting.
6. A device according to any one of claims 1 to 5, wherein the pick-up element (1) comprises an optically transparent rod.
7. A device according to claim 6, wherein the rod (1) has a rectangular cross-section.
8. A device according to any one of claims 1 to 7, wherein the normals to the curved path at each end thereof meet at an angle that lies in the range of from 60° to 180° .
9. A device according to any one of claims 1 to 8, wherein the curved path has at least a section which has a constant radius of curvature.
10. A device according to any one of claims 1 to 9, wherein the optical loss introduced to the optical fibre (3) is less than or equal to 6dB.
11. A device according to claim 10, wherein the optical loss introduced to the optical fibre (3) is less than or equal to 3dB.

Patentansprüche

1. Optische Kopplungsvorrichtung zum Auskoppeln niedriger Leistungspegel optischer Strahlung aus einer optischen Faser (3), die einen Refraktionsindex von n_1 bei oder nahe ihrer Oberfläche hat, und die eine Primärbeschichtung aus Kunststoffmaterial hat, wobei die Kopplungsvorrichtung ein Aufnahmerelement (1) aufweist, das einen Refraktionsindex n_3 hat, wobei das Aufnahmerelement (1) einen Wellenleiterpfad aufweist, von dem zumindest ein Teil gekrümmt ist, um einen gekrümmten optischen Wellenleiterpfad zu bilden, wobei die

Kopplungsvorrichtung ebenso eine Rückhalte-einrichtung zum Rückhalten der optischen Faser in einer gekrümmten Position aufweist, die zumindest im wesentlichen mit der inneren Oberfläche (4) des gekrümmten Pfades übereinstimmt, wobei die Refraktionsindizes des Aufnahmerelementes und der Oberfläche der optischen Faser, n_3 und n_1 , und der Radius der Krümmung, R , in mm der inneren Oberfläche des gekrümmten Pfadabschnittes des Aufnahmerelementes so gewählt sind, daß $n_3 > n_1 (1 - 0,125/R)$ ist, wobei R größer als oder gleich 3 ist, dadurch gekennzeichnet, daß die Rückhalte-einrichtung durch eine Klemmeinrichtung gebildet ist, die einen Block (2) aus einem Material aufweist, der eine konvexe Oberfläche hat, wobei eine Nut (8) in der konvexen Oberfläche bereitgestellt ist, um den optischen Wellenleiter (3) über der konvexen Oberfläche anzuordnen, und eine Einrichtung zum Zusammenhalten des Blockes und des Aufnahmerelementes, um die optische Faser in der Nut positioniert zu halten, und wobei die Klemmeinrichtung so ist, um die optische Faser ausreichend fest zu halten, um ihre Primärbeschichtung zu deformieren, so daß bei Verwendung optische Strahlung aus der optischen Faser leckt und in den gekrümmten Pfad gekoppelt wird.

2. Vorrichtung gemäß Anspruch 1, worin die Klemmeinrichtung bewegbar relativ zu dem Aufnahmerelement ist.
3. Vorrichtung gemäß Anspruch 1 oder 2, worin $n_3^2 < (n_1^2 (1 - 0,25/R) + (0,125/R)^2 + 1)$ ist.
4. Vorrichtung gemäß einem der Ansprüche 1 bis 3, worin die Dicke des Aufnahmerelementes (1) in mm in der Ebene normal zu der Schnittstelle zwischen dem Aufnahmerelement und der optischen Faser (3) geringer als $0,44R - 0,18$ ist.
5. Vorrichtung gemäß einem der Ansprüche 1 bis 4, worin das Aufnahmerelement (1) steif und selbsttragend ist.
6. Vorrichtung gemäß einem der Ansprüche 1 bis 5, worin das Aufnahmerelement (1) einen optisch transparenten Stab aufweist.
7. Vorrichtung gemäß Anspruch 6, worin der Stab (1) einen rechteckigen Querschnitt hat.
8. Vorrichtung gemäß einem der Ansprüche 1 bis 7, worin die Normalen zu dem gekrümmten Pfad an dessen jedem Ende sich in einem

Winkel treffen, der in dem Bereich von 60° bis 180° liegt.

9. Vorrichtung gemäß einem der Ansprüche 1 bis 8, worin der gekrümmte Pfad zumindest einen Abschnitt hat, der einen konstanten Krümmungsradius hat.
10. Vorrichtung gemäß einem der Ansprüche 1 bis 9, worin der optische Verlust, der durch die optische Faser (3) eingeführt wird, kleiner oder gleich 6dB ist.
11. Vorrichtung gemäß Anspruch 10, worin der optische Verlust, der durch die optische Faser (3) eingeführt wird, kleiner oder gleich 3dB ist.

Revendications

1. Un dispositif de couplage optique servant à coupler des niveaux de basse puissance d'un rayonnement optique hors d'une fibre optique (3) dont l'indice de réfraction est n_1 à sa surface ou au voisinage de celle-ci et qui est pourvue d'un revêtement primaire en matière plastique, le dispositif de couplage comprenant un élément détecteur (1) dont l'indice de réfraction est n_3 , l'élément détecteur (1) comprenant un trajet de guidage d'onde dont au moins une partie est incurvée afin de former un trajet incurvé de guidage d'onde optique, le dispositif de couplage comprenant également un moyen de retenue pour retenir la fibre optique dans une position incurvée qui se conforme au moins sensiblement à la surface extérieure (4) du trajet incurvé, les indices de réfraction de l'élément détecteur de la surface de la fibre optique, n_3 , n_1 , et le rayon de courbure R, en mm de la surface intérieure de la partie de trajet incurvé de l'élément de détection étant choisis d'une manière telle que $n_3 > n_1(1 - 0,125/R)$, R étant supérieur ou égal à 3, caractérisé en ce que le moyen de retenue est constitué par un moyen de serrage comprenant un bloc (2) de matière à surface convexe, une rainure (8) étant ménagée dans la surface convexe afin de positionner le guide d'onde optique (3) au-dessus de la surface convexe, et un moyen servant à maintenir ensemble le bloc et l'élément détecteur, de façon à saisir la fibre optique positionnée dans la rainure, et le moyen de serrage est apte à saisir la fibre optique d'une manière suffisamment étroite pour déformer son revêtement primaire d'une manière telle que, en utilisation, un rayonnement optique fuit de la fibre optique, et est couplé dans le trajet incurvé.
2. Un dispositif selon la revendication 1 dans lequel le moyen de serrage est mobile par rapport à l'élément détecteur.
3. Un dispositif selon la revendication 1 ou la revendication 2, dans lequel $n_3^2 < (n_1^2(1 - 0,25/R) + (0,125/R)^2 + 1)$.
4. Un dispositif selon l'une quelconque des revendications 1 à 3, dans lequel l'épaisseur de l'élément détecteur (1) en mm dans le plan normal à l'interface entre l'élément détecteur et la fibre optique (3) est inférieur à $0,44 R - 0,18$.
5. Un dispositif selon l'une quelconque des revendications 1 à 4 dans lequel l'élément détecteur (1) est rigide et se supporte lui-même.
6. Un dispositif selon l'une quelconque des revendications 1 à 5 dans lequel l'élément détecteur (1) comprend une tige optiquement transparente.
7. Un dispositif selon la revendication 6, dans lequel la section transversale de la tige (1) est rectangulaire.
8. Un dispositif selon l'une quelconque des revendications 1 à 7, dans lequel les normales au trajet incurvé à chacune de ses extrémités se rencontrent selon un angle qui est compris dans la plage de 60° à 180°.
9. Un dispositif selon l'une quelconque des revendications 1 à 8 dans lequel le trajet incurvé comprend une section dont le rayon de courbure est constant.
10. Un dispositif selon l'une quelconque des revendications 1 à 9 dans lequel la perte optique introduite dans la fibre optique (3) est inférieure ou égale à 6 dB.
11. Un dispositif selon la revendication 10, dans lequel la perte optique introduite dans la fibre optique (3) est inférieure ou égale à 3 dB.

Fig.1.

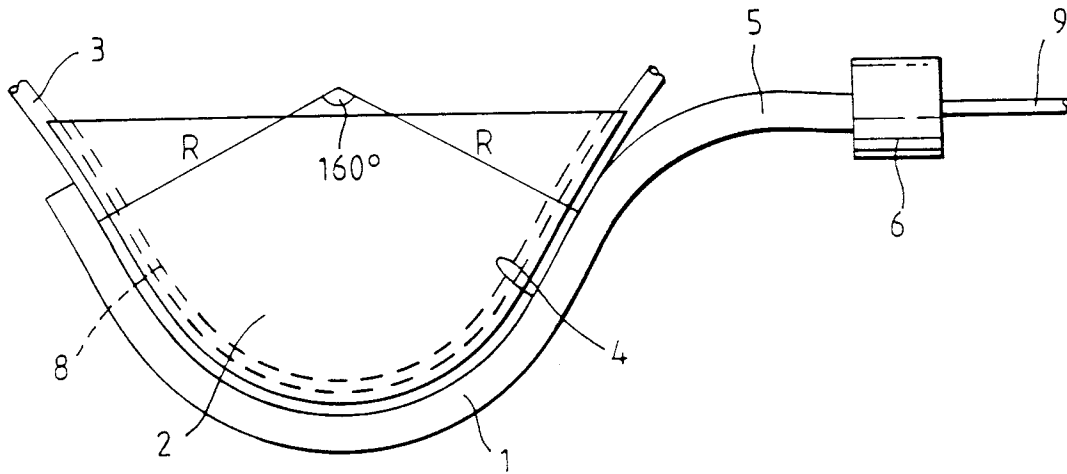


Fig.1a.

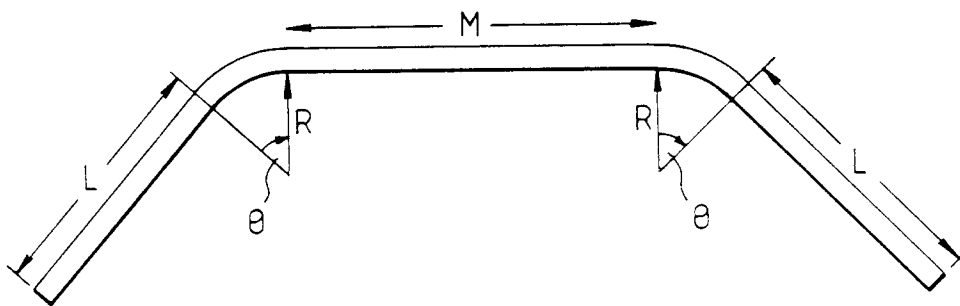


Fig. 2.

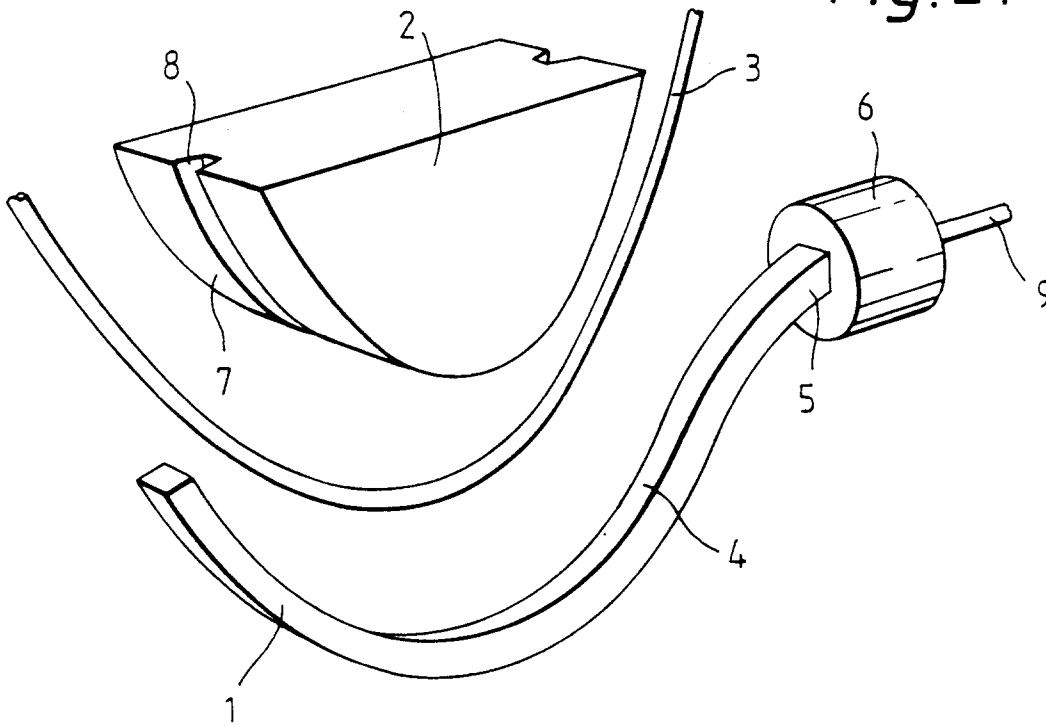


Fig. 3.

